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FIELD TESTS OF AM3 LANDING MAT

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H. L. Green

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Advanced Research Projects Agency

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ARMY-MRC VICKSBURG, MISS.

FOREWORD

This investigation was sponsored by the Advanced Research Projects Agency (ARPA), Washington, D. C., under ARPA Order No. 285. The project was authorized by the Naval Air Engineering Center (NAEC), Naval Air Engineering Laboratory (Ship Installations) (NAEL-SI), Philadelphia, Pa., in Project Order No. 3-4070, dated 24 April 1963, to the U. S. Army Engineer Waterways Experiment Station (WES), Vicksburg, Miss. Four subsequent amendments to the project order extended the expiration date to 30 September 1965. The test directive outlining the test procedures was forwarded to WES by NAEC on 9 November 1964 (see Appendix A).

The field tests were conducted by personnel of the WES Soils Division in April and May 1965. Engineers actively concerned with the planning, testing, analysis, and report phases of this study were Messrs. W. J. Turnbull, A. A. Maxwell, W. L. McInnis, Robert Turner, Hugh L. Green, and Gordon L. Carr. This report was prepared by Mr. Green.

Col. John R. Oswalt, Jr., CE, was Director of the WES during the investigation and preparation of this report. Mr. J. B. Tiffany was Technical Director.

CONTENTS

SUMMARY

Field tests were conducted on AM3 landing mat to determine the capability of the mat to support helicopter operations when floated on water and when placed on marshy soil having a CBR of about 0.25 percent. The mat was an aluminum, cellular-type structure filled with polyurethane foam, with top and bottom facings fabricated from aluminum alloy sheets. The side and end connectors were of an extruded aluminum alloy. The directive for the tests is given in Appendix A.

The individual panels were assembled on a pond into an approximately 62- by 90-ft floating landing pad. The pad was subjected to repeated landings and taxiing operations of a UH-34D helicopter with loads ranging to 13,000 lb and landing forces ranging to 2.41 g. The pad was then disassembled, moved to a marsh area, and reassembled. The pad was again subjected to operations of a helicopter with a gross weight of 12,000 lb and landing forces of 2.18 g.

The mat successfully withstood all helicopter operations with the only structural damage being minor cracks in some of the welds. The cracks developed during landings of the helicopter as the pad floated on water, but they did not appear to impair the capability of the mat to support the weight of the aircraft. After use, the mat can be disassembled, moved to another location, and reassembled for reuse.

The submergence and adhesion tests indicated that panels would adhere to clay soil when submerged under certain load conditions, and that the use of a membrane beneath the pad would alleviate this adhesion.

It is recommended that the AM3 design be modified to reduce panel size (and thus weight) and to improve the connectors so that the mat can be placed more easily; that an antiskid coating be used that is unaffected by water; and that a membrane be used between the mat and cohesive soil.

The tests showed that the use of AM3 mat as expedient surfacing material for remote airfields is feasible. Modifications to the design to reduce both the weight of the panel and the effort required for panel assembly are recommended.

FIELD TESTS OF AM3 LANDING MAT

PART I: INTRODUCTION

Background

1. The ability to utilize air power to support military operations in remote areas of the world is of prime significance and is dependent upon the availability of operational airfields. Natural conditions, such as extremely low-strength soil and inundated surfaces, in some remote areas sometimes preclude construction and maintenance of conventional airfields. A study and an analysis of these problems were made under the direction of the Advanced Research Projects Agency (ARPA). These resulted in the design and fabrication of a test quantity of aluminum, cellular-type landing mat panels filled with polyurethane foam which it was hoped would support helicopter operations when placed on a pad on soft ground or floated on water. This mat was designated AM3.

Objectives of Investigation

2. The objectives of this investigation were to:

   a. Determine the effort involved in assembling and disassembling a 62- by 90-ft AM3 pad on water and on a marsh, and investigate the feasibility of reuse of the pad panels.

   b. Determine the ability of a pad of the panels when placed on water and on a very weak subgrade to withstand sustained helicopter landings, takeoffs, and taxiing operations.

   c. Determine the time and effort involved in removing and replacing a panel from the interior of the pad complex both on the water and on the marsh.

   d. Investigate the possibility of water seepage into the core of the panels.

   e. Study the adhesion developed between individual panels and the soil on which they were placed after load was applied to the panels.

Scope of Investigation

3. The desired data were obtained by tests and inspection as follows:

   a. In Phase I of the field tests, the 62- by 90-ft mat pad was assembled on water and subjected to helicopter landings, taxiing, and takeoffs, after which it was disassembled.

   b. The mat pad was reassembled in Phase II on a weak, natural marsh and again subjected to helicopter operations.

   c. Individual interior panels were removed and replaced during both test phases, and also inspected for water migration.

   d. In the adhesion tests, individual panels were placed on a simulated marsh and subjected to various loads to simulate aircraft static loads for periods of time, after which the force required to pull the panels out of the marsh was determined.

   e. Bundles and individual panels of AM3 mat were weighed, measured, and inspected. A few panels were assembled prior to and after the completion of field tests to determine if any damages or irregularities were present in individual panels.

PART II: DESCRIPTION OF MAT AND HELICOPTER

Mat Bundles

4. The mat was shipped in bundles of seven panels each. Full-size panels and half panels were bundled separately (photograph 1). Panels were supported on wooden pallets and were individually separated by wooden wedges placed in the connectors to prevent adhesion between the antiskid surfacing and the bituminous coating on the bottom of panels. Overall bundle dimensions including dunnage were: length, 100.5 in.; width, 40.75 in.; and height, 47.0 in. The bundles were banded with 5/8-in.-wide steel straps. The average weight of a bundle of full-size panels was 1395 lb.

Mat Panels

5. Photograph 2 shows a whole and a half panel of AM3 mat. For this investigation, 237 whole panels and 21 half panels of AM3 mat were furnished. The AM3 mat was made by the Aluminum Corporation of America (ALCOA), New Kensington, Pa., under contract with the Department of the Navy. Overall dimensions of the panels were: length, 97-5/16 in.; width, 39-3/16 in.; and thickness, 5.520 in. The width of the top side of the panels averaged 0.09 in. more than the width of the bottom side. This caused a crown to develop in the pad during the pond tests, as described subsequently in paragraph 10. The average weight of one panel was 183.14 lb without connectors, and 212.64 lb with connectors. The weight of the panel with connectors per square foot of placing area was 7.87 lb. The placing area of one panel with connectors was 27.02 sq ft.

6. The bottom of the panels was coated with a waterproofing bituminous material and the top was coated with an antiskid compound. Both the sides and the end connectors were extruded from aluminum alloy, and the top and bottom facings were aluminum alloy sheets. The core was an aluminum, cellular-type structure filled with polyurethane foam to prevent water from entering the individual cells in case a leak developed in the panel structure. The panels were connected by locking bars at the top and

bottom, which were held together by aluminum bolts. The top and bottom connectors with bolts and tools for assembly are shown in photograph 3. The tool shown on the left in photograph 3 was used in pairs by two men to lift and shift the position of the mat. The small brush was for cleaning debris from the bolt holes.

7. The installation instructions accompanying the AM3 mat noted that the panels were not all of uniform dimension and some panels were not interchangeable due to the prototype nature of initial fabrication. Sixty-four panels in the shipment, marked with yellow coding, were 1/16 in. deficient in width. However, these panels were used successfully in both Phase I and Phase II tests with only minor difficulty in assembly. Sixteen additional panels, marked with white coding, contained discrepancies of $\pm$ 3/16 in. in width and were not used in test Phases I and II. These 16 panels were intermixed with other panels in a trial assembly on a flat, hard surface with only minor difficulty. Although the difference in width was visible, no major problems were encountered in placing the nonuniform panels with other panels. The dark-colored panels in photograph 4 are the dimensionally deficient panels assembled in the layout.

Helicopter

8. A UH-34D helicopter with a basic weight of 7732 lb and a maximum weight of 13,000 lb was used in the tests. The rotary-winged aircraft contained a single, conventional-type landing gear configuration which consisted of two main gear wheels plus a single tail wheel. With the aircraft empty, the tire-print area for each main tire was 79 sq in. and the tire pressure was 57 psi. With the helicopter loaded to 12,000 lb, the tire-print area increased to 88.2 sq in. and the tire pressure was 58 psi. These areas were computed from actual tire prints of the aircraft. An accelerometer and a recorder were installed in the helicopter to indicate the total loads imposed on the mat under vertical deceleration of the aircraft.

PART III: REMOTE AREA TESTS

Site Descriptions

9. The field tests of the AM3 mat were conducted on Government-leased land approximately 12 miles south of the U. S. Army Engineer Waterways Experiment Station (WES). The first test, designated Phase I, was conducted on a pond (photograph 5) which has a maximum depth of water of 8 to 10 ft. The water depth in the vicinity of the test pad ranged from about 1 to 5 ft. The second test, designated Phase II, was conducted on a marsh about 1.5 miles from the pond (photograph 6). This area contained some surface water and a considerable amount of vegetation; however, the vegetation was less than 18 in. in height. Trafficability cone penetrometer measurements indicated that the CBR values at the surface, 6-in. depth, and 18-in. depth were 0, 0.17, and 0.30, respectively.

Test Phase I

Mat placement

10. The test directive (Appendix A) required that the test on water be performed prior to the test on soft ground. The mat was placed on the water in rows or runs consisting of 11 panels per run, with alternate runs consisting of 10 whole panels and 2 half panels. Each successive 90-ft run was placed along and parallel to the landside of the completed complex so that the pad would be assembled in relatively shallow water (photograph 7). As the recommended torque of 45 ft-lb was applied to the connector bolts, the pad began to bow, with the center of the pad rising higher than the outside edges in a direction parallel with the runs (photograph 8). This made it difficult to assemble additional panels (photograph 9), since each additional panel had to be submerged to the level of the last run of panels placed. A few bolts were broken (photograph 10) when the 45 ft-lb torque was applied to them. To remedy this, the torque was reduced to 30 ft-lb; the pad then tended to flatten out, and the bow in the pad was reduced

somewhat since the reduced torque relieved some of the strain in the center portion of the pad. It was decided to continue to apply only a 30 ft-lb torque to the remainder of the bolts and to reduce the torque of those previously tightened from 45 ft-lb to 30 ft-lb.

11. A 13-man crew placed an average of five runs of panels in a day. Rain delayed work on one day and only four runs were placed; however, during one 2-hr period, two runs were placed with an 11-man crew. The pad consisted of 19 runs of panels and was approximately 62 by 90 ft in size (photograph 11). The effort required to assemble the pad on the water was 308 man-hours. At completion, a bow was still evident in the pad, with the center runs higher than the outside runs, which were partially submerged. Photograph 12 is a close-up of this condition. Two 4-1/2-in.-diam creosoted posts were driven 3 ft into the ground at each corner of the pad to restrict movement of the pad during operations (photograph 11). Each pair of posts was wired together for added stability during operations.

Pad measurements

12. Prior to the helicopter landings, cross sections and profile measurements were made on the pad together with waterline measurements along edges of the pad. Locations of these measurements are shown in plates 1 and 2. Freeboard measurements were made at ends of the pad. Diagonal measurements were made to determine any distortion that might occur during testing. These measurements were made at intervals during and at the completion of tests. Table 1 shows the diagonal measurements. Gages shown in photograph 11 at the upper left corner and at the right side in the middle of the pad were used in conjuction with cameras to record vertical movement of the pad during helicopter takeoffs and landings. The profiles in plate 3 show that the outside edges of the pad rose slightly when the helicopter was on the pad. This occurred as the bow at the center leveled out somewhat and the outside edges of the pad were pushed up. Plates 4 and 5 show additional cross sections and deflections, respectively. Most of the difference in initial and final elevation of the pad can probably be attributed to the absorption of water by individual panels.

Helicopter operations on pond

13. Photograph 13 shows the UH-34D helicopter making its first approach to the pad. The landing was made very cautiously, with the full weight of the craft being eased down on the pad. Photograph 14 shows the aircraft after its first landing, with approximately 14,000-lb total weight on the pad. Table 2 summarizes the landings, weights, and gravity forces during test Phase I. The initial operations consisted of several landings with gravity forces ranging up to 2.12. The basic weight of the helicopter with maximum fuel load was 10,000 lb. To achieve increased gravity forces, the helicopter dropped from a height of 4 or 5 ft with no power. During these drops, approximately 0.5-in. elevation change was noticed in the two gages recording the pad's elevation on the water. After several drops, the helicopter performed taxiing operations on the entire pad, along the joints, and around the edge with no evidence of any unusual occurrences. Photograph 15 shows the front wheels of the aircraft within 4 ft of the mat edge during taxiing operations. Water can be seen just covering the edge of the mat at this point. No unusual conditions other than minor pumping of water between joints were observed during any of the operations. The pilot indicated that normal landings on the pad were softer than ordinary landings on firm ground.

14. After it was determined that initial landings had only minor effects on the pad, the helicopter was loaded with sandbags to increase its gross weight to 11,000 lb, and two landings were made with no unusual results. The weight was then increased to the maximum allowable, 13,000 lb (photograph 16). Drops were made with gravity forces up to 2.41 (table 2). The craft was taxied around the pad for approximately 15 min. The main difference observed between operations of the minimum and fully loaded craft was increased water and air turbulence created by additional power required to lift the helicopter. During the seventeenth and final landing, the posts at one corner of the pad were pushed over, and the pad with the helicopter on it began to drift across the pond. After the helicopter took off, the pad was easily repositioned by several men who used long poles to push the pad around. A shear pin from the shaft of the swivel wheel on the helicopter tail wheel was broken during one of the drops, but this did not have

any effect on the surface of the pad.

Panel removal

15. One panel located in the middle of the pad was removed to determine the time and effort required to remove and replace a panel. All bolts around the panel were loosened, and the side-connector bars were forced out. One bar was bent out of shape and another was broken during this operation (photograph 17). The time required for eight men to remove the panel was 35 min. Replacing the panel was somewhat more difficult, as the panel had to be pushed down into the water to the level of the pad surface and held in position while the connectors and bolts were replaced. The time required for eight men to replace the panel was 50 min. The total effort required to remove and replace the panel was 11-1/3 man-hours. This first operation was accomplished with an untrained crew, and it is evident that a trained crew could accomplish the operation in less time.

Pad disassembly

16. The disassembly of the pad was accomplished by 13 men in 8-1/2 hr, or a total of 110.5 man-hours, without any major problems. Water had entered the core of some of the panels through minute cracks in the welded joints of the extruded aluminum connectors, causing an increase in panel weight. Water was observed running out of weld cracks as the panels were removed from the pond. The weight of 10 panels selected at random had increased an average of 30 lb per panel due to water in the core; the weight of one panel had increased 127 lb. After the pad had been completely disassembled, individual panels were stacked into bundles and moved to the marsh for test Phase II.

Test Phase II

Mat placement

17. The initial work at the marsh site was laying out the test area and attempting to move the bundles of AM3 on skids to the test area. A D4 bulldozer towing the first bundle from the stockpiled area to the center of the marsh was immobilized in the mud. Photograph 18 shows the immobilized bulldozer and the panels being hand-carried to the area.

Because of the increased weight of panels caused by water absorption and the ankle-deep muck, four men were required to carry a panel. No attempt was made to clear or level the area prior to placement of the mat; however, continuous walking in the area during assembly operations pushed the vegetation into the mud and rendered the area relatively level (photograph 19). It was finally decided to use a tracked-amphibian vehicle (Weasel) to tow the mat bundles and position them around the pad site. This vehicle was much lighter than the bulldozer and had wider tracks which enabled it to negotiate the marsh with little or no difficulty (photograph 20).

18. The main problem encountered in laying the AM3 mat on the marsh was the assembly of connectors at joints between runs. The portion of the pad already in position settled into the mud due to construction activity on the pad. Therefore, it was necessary to push the new panels down to the level of the pad before they could be successfully engaged and connected. The marshy surface had been churned by foot traffic the previous day, and the upper 1 or 2 in. had begun to dry out and become crusty; this made it difficult to push a new panel down to the level of the pad and the connector down to the correct position. Several longer bolts were used in the connector bars to facilitate engaging the lower connectors. Once the connectors were in the correct position, the longer bolts were removed and the standard bolts were inserted. A torque of 30 ft-lb was applied to all bolts, and the mat was swept to remove dirt and mud.

19. A small depression containing water was located on the ground between runs 14 and 15 and extended the length of approximately two panels. To evaluate this condition, the panels were laid over the natural area without any attempt being made to level this depression. After mat laying was completed, a depression of approximately 1.75 in. was noted at the joint of the two runs (photograph 21). Investigation of this area during disassembly revealed that the bottom panel connectors were not properly engaged with the bottom connector bar at the joint. The proper engaging of the bottom-connector bars was the most difficult problem encountered during assembly. However, this was the only point on the pad where the bottom-connector bars were found to be disengaged.

20. The mat laying was completed on the marsh in approximately 3 days with a total effort of 528 man-hours. Aerial and ground views of the completed pad are shown in photographs 22 and 24, respectively.

Pad measurements

21. Cross sections and profile measurements were made on the assembled pad (see plate 6 for location of measurements) prior to testing and at intervals during and at completion of the tests. Diagonal measurements were also made (table 1). Deflection curves in plate 5 indicate a maximum deflection of 0.2 in. under the loaded helicopter. The profiles and cross sections shown in plates 3 and 7, respectively, indicate effects resulting from the outside edges of the pad being higher in some cases due to concentrated landings near the center of the pad which caused this portion to settle deeper in the marsh.

Helicopter operations on marsh

22. Prior to any landings being made on the pad, the CBR of the soil was determined at various intervals around the perimeter of the pad. The CBR of the top 18 in. at nine locations averaged 0.20 percent. On its first approach to the pad, the helicopter raised considerable dust as soil particles and other foreign matter were blown from the surface (photograph 23). After that, the surface remained clean; therefore, there was no dust problem during subsequent operations (photograph 24). During the initial tests, the helicopter was loaded to 10,000 lb and 11 landings were made with gravity forces of 1.20 to 2.13 (table 2). The aircraft was taxied over the entire pad, along the joints, and around the edges with no evidence of any unusual occurrences or failures (photograph 24).

23. The helicopter was then loaded with sandbags to 10,500 lb for one landing and then to 12,000 lb. Just before the thirteenth landing was undertaken, water from two trucks holding approximately 1000 gal each was sprinkled over the pad and around the edges to maintain the marshy condition. With the maximum load attainable under the prevailing weather conditions, the aircraft made 19 landings, making a total of 31 landings on the pad in Phase II. The maximum gravity force attained was 2.18 and was with the 12,000-lb load.

24. Several rolling landings were made diagonally across the pad in

these tests with the 12,000-lb load. The helicopter touched down on one corner, taxied to the opposite corner, and halted abruptly at the pad's edge (photograph 25). This simulated a normal landing for a helicopter operating with a maximum cargo load. The craft again taxied over the entire pad, with the main gear wheels coming within inches of the edge (photograph 26). The helicopter also taxied along and across the depressed joint between runs 14 and 15 (paragraph 19). The depressed area was trafficked with the tail wheel (photograph 27) and main gear wheels (photograph 28) with no adverse effects being noted. The only visible damage to the pad was flaked-off antiskid compound. This was particularly evident when one tire was braked and 360-deg turns were made. Loose antiskid compound was observed on 20 panels during and after the tests. It is believed that exposure to water during the pond tests weakened the bond between the antiskid compound and the panels. The CBR was determined at each corner of the pad and also near the center of the pad after one panel was removed. The average CBR in the top 12 in. was 0.26 percent.

Panel removal

25. To determine the effort required to remove and replace a panel in the pad, two panels were removed, one near the center of the pad (where a CBR pit was later dug) and the other near the depressed area in run 14. Removal of the center panel required three men working for 15 min. All four bars were damaged during removal of the panel. This panel was not replaced. Removal and replacement of the second panel required two men working for 25 min, or 0.83 man-hours. None of the connector bars were damaged during the operation. The panel removal on the marsh pad was considerably easier than on the pond pad.

Pad disassembly

26. Disassembly of the pad on the marsh required eight men working 15 hours, or 120 man-hours. This does not include the effort expended in cleaning mud from the panels for reuse. No major problems were encountered in disassembling the pad, although the workers were handicapped by the marshy condition. Loading the mat for removal after disassembly of the pad was hampered by the soft ground; trucks could not maneuver in the marsh, and the Weasel again had to be used to tow the mat on skids to firm ground.

The condition of the marsh after the pad was removed is shown in photograph 29.

PART IV: SUBMERGENCE AND ADHESION TESTS

Submergence Tests

27. In Phase I tests, it was evident that some of the panels were absorbing water. One panel which weighed 183 lb prior to the test and 267 lb after 7 days on the pond was selected for a submergence test to determine how much additional water it would absorb. This panel was completely submerged with 750 lb of ballast for 10 days. After the ballast was removed, the panel floated to the surface and had an average of 3 in. of freeboard around its edges (photograph 30). Its weight had increased t, 292 lb, a gain of 25 lb and a total gain of 109 lb. It is believed that hairline cracks in the corner welds of the panel (photograph 31) allowed water to seep into the core. About 25 to 30 percent of the panels had such cracks; these panels were easily detected as water ran out of the cracks when one end of a panel was elevated.

Adhesion Tests

28. Adhesion tests were conducted to determine the bond between the bottom of the AM3 panels and the underlying mud. A 12-ft-square pit approximately 3 ft deep was constructed at the WES for this purpose. The soil was a clay (CL) having an average liquid limit of 39 and an average plasticity index of 17 (plate 8). To create the marshy condition desired for the test, the pit was flooded with water and allowed to soak for 2 days (photograph 32). The pit was then backfilled with loose natural clay to create a muck.

29. In the first test, one unloaded panel and one panel loaded to 8000 lb were placed in the pit (photograph 33). After 3 hr, the weight was removed from the loaded panel and an attempt was made to pull the panels from the mud. An overhead crane equipped with a dynamometer measuring the pull was used for the lifting. The unloaded panel was pulled out with a 450-lb pull. On the first attempt to pull the panel which had been loaded, the steel straps around the panel broke at 2000-lb pull without

moving the panel (photograph 34). Another attempt was made the next day, and the panel was removed with a 4400-lb pull. The unloaded panel was again placed in the pit; this time a 475-lb pull was required to remove it. A third panel was loaded to 8000 lb for 4 hr and then unloaded. A 1725-lb force was required to pull one end of this panel out of the muck.

30. A second test was made to determine if the panels would float on water after being subjected to the test conditions described above. Two panels were again put in the pit, one loaded to 8000 lb and one unloaded. The load was removed after 4 hr, and the pit was flooded. The unloaded panel floated when the water level rose to 2.5 in. of freeboard. The panel which had been loaded remained underwater. After 48 hr an attempt was unsuccessfully made to dig this panel out, and a crane was required to remove it from the muck. Two panels were next put in the pit and loaded to 2000 and 4000 lb, respectively, for 4 hr. The weights were then removed and the pit was flooded; both panels floated with approximately a 3-in. freeboard.

31. A 0.006-in.-thick polyethylene membrane was next used under the panels to determine the advantages of decreasing adhesion of mat to soil. Two panels were each loaded to 8000 lb for 3 hr with one panel having a single layer of polyethylene and the other having a double layer underneath. The load was then removed and the pit was flooded; each panel floated easily with a 4-in. freeboard. No difference was observed in the effect of the single layer and the double layer of polyethylene.

PART V: SUMMARY OF RESULTS, CONCLUSIONS, AND RECOMMENDATIONS

Results

32. The following results were obtained in this investigation:

<u>a</u>. A 62- by 90-ft pad of AM3 mat was placed on water in 308 man-hours and on marsh in 528 man-hours by relatively untrained personnel.

<u>b</u>. The antiskid coating began flaking off, leaving bare metal, during Phase II tests after being exposed to water during Phase I tests.

<u>c</u>. In Phase I tests, the AM3 mat withstood taxi operations and 17 landings of the UH-34D helicopter with gross loads to 13,000 lb and gravity forces to 2.41.

<u>d</u>. During helicopter operations in Phase I tests, minor cracks developed in the welded corner joints of the extruded aluminum connectors which permitted an average of 30 lb of water per panel to enter the cores of the panels. Polyurethane foam in the cores somewhat restricted the amount of water absorption and prevented the panel from sinking.

<u>e</u>. Removing and replacing a panel in the interior of the pad during Phase I tests required 11-1/2 man-hours.

<u>f</u>. In Phase II tests, the AM3 mat pad withstood taxi operations and 31 landings of the UH-34D helicopter with gross loads to 12,000 lb and gravity forces to 2.17.

<u>g</u>. Other than minor cracks in the welded corner joints of extrusions, no structural damage to panels resulted from helicopter operations.

<u>h</u>. Removing and replacing a panel in the interior of the pad during Phase II tests required 0.83 man-hours.

<u>i</u>. Sufficient adhesion developed between loaded panels and the cohesive soil to prevent the panels from floating when the area was inundated.

<u>j</u>. Membrane placed between loaded panels and cohesive soils permitted the panels to float when the area was inundated.

Conclusions

33. From this investigation of the AM3 mat, the following conclusions are believed to be warranted:

a. A helicopter loaded to maximum operating load (13,000 lb) can successfully accomplish landings of maximum force, taxiing operations, and takeoffs on the AM3 mat pad placed on both water and marsh.

b. The placing rates can be increased by reducing panel size (thus reducing weight), and by improving connectors to eliminate the use of an excessive number of bolts.

c. After being used in one location, the pad can be disassembled and moved to a new location and reassembled for reuse.

d. A membrane placed between the mat and cohesive soil will prevent adhesion of mat to soil and permit the mat to float if the area is inundated, or will facilitate removal of the mat if it is to be used again elsewhere.

Recommendations

34. It is recommended that:

a. The AM3 design be modified to reduce panel size (thus reducing weight) and to improve the connectors.

b. A primer be applied to the panels to eliminate glare once the antiskid compound is removed, and an improved antiskid coating be used that is unaffected by exposure to water.

c. A membrane be used between the AM3 mat and cohesive soil if it is desired that the mat float when the area is inundated or if the mat is to be removed for reuse.

Table 1

Diagonal Measurements of Pad Prior to, During, and After Helicopter Landings, Phases I and II

Direction Measured	Distance, ft	Remarks
	Test Phase I	
Southeast to northwest	109.89	Prior to landings
Southeast to northwest	109.82	After 7 landings
Southeast to northwest	109.87	After 17 landings
Southwest to northeast	109.00	Prior to landings
Southwest to northeast	109.00	After 7 landings
Southwest to northeast	109.02	After 17 landings
	Test Phase II	
Southeast to northwest	109.32	Prior to landings
Southeast to northwest	109.28	After 11 landings
Southeast to northwest	109.31	After 31 landings
Southwest to northeast	109.58	Prior to landings
Southwest to northeast	109.51	After 11 landings
Southwest to northeast	109.58	After 31 landings

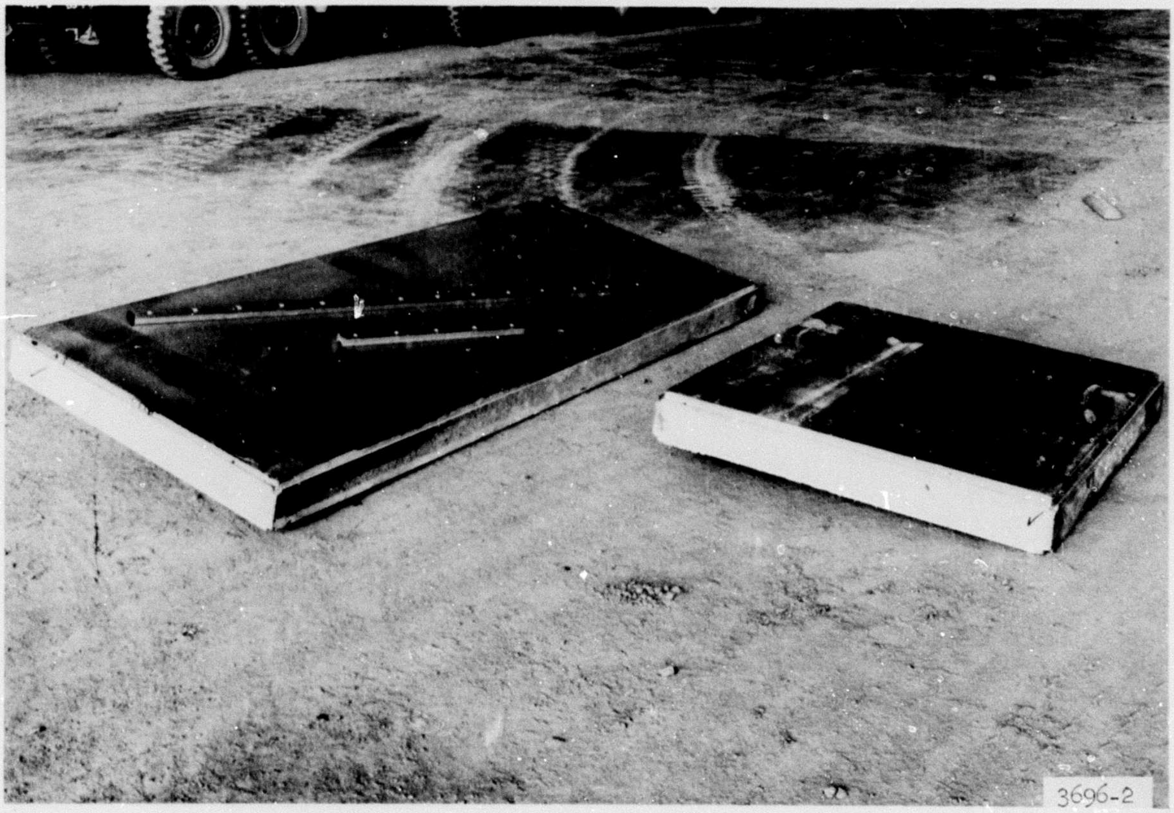
Table 2

Helicopter Operations During Tests

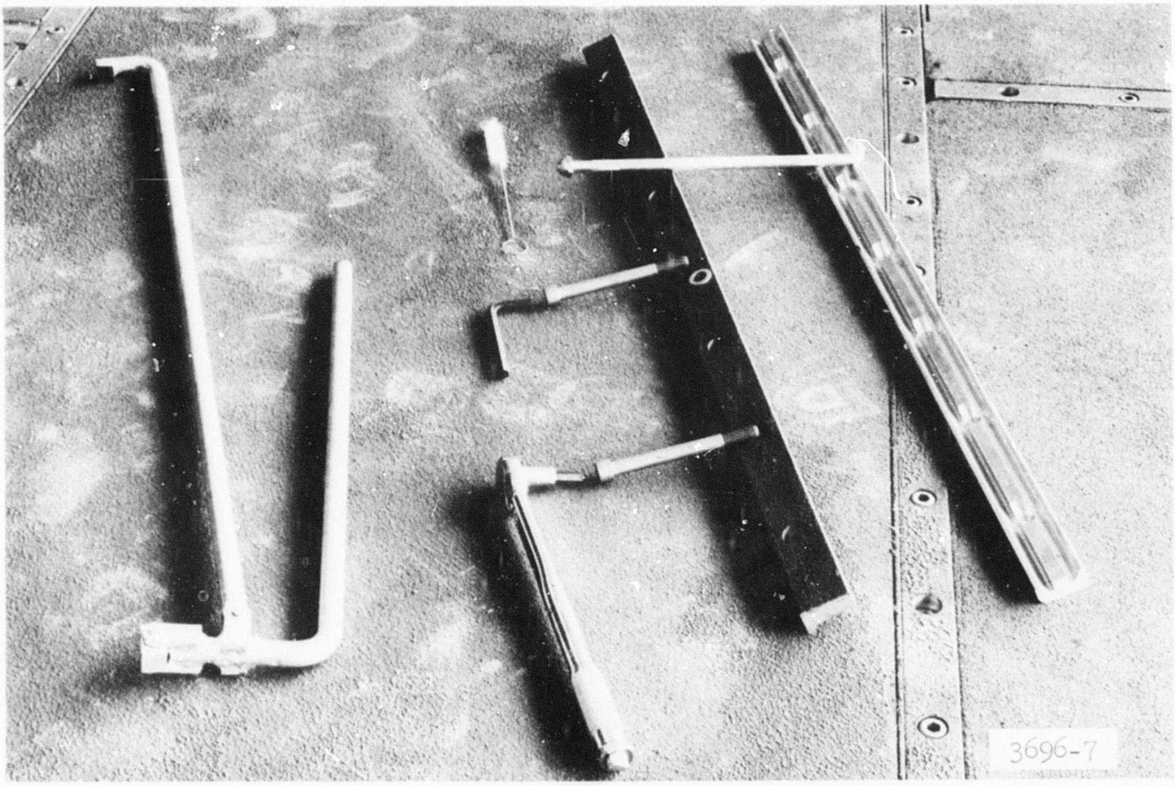
Landing No.	Gravity Force	Load, lb	Remarks
		Phase I	
1	1.28	10,000	
2	1.35	10,000	
3	1.30*	10,000	
4	2.12	10,000	5-ft drop, water squirted up between joint
5	1.96	10,000	5-ft drop, 10-min taxiing on pad
6	1.20*	10,000	
7	1.91	11,000	Sand bags added prior to drop
8	2.14	11,000	
9	1.60	13,000	Additional weight added, 15-min taxiing
10	1.97	13,000	
11	2.10	13,000	5-ft drop
12	2.41	13,000	5-ft drop
13	1.84	13,000	
14	1.66	13,000	
15	1.97	13,000	4-ft drop and 8-min taxiing
16	1.52	13,000	
17	1.36	13,000	
		Phase II	
1	1.54	10,000	
2	1.63	10,000	
3	1.83	10,000	Taxiing for 8 min
4	1.94	10,000	Taxiing along edge and joints
5	1.98	10,000	Drop 4 ft
6	2.00*	10,000	Drop 4 ft
7	1.97	10,000	Drop 4 ft
8	2.10	10,000	Drop 3 ft
9	2.13	10,000	Drop 4 ft
10	1.20*	10,000	
11	1.30*	10,000	
12	1.10*	10,500	
13	1.38	12,000	Diagonal rolling landing
14	1.75	12,000	Diagonal rolling landing
15	1.86	12,000	Drop 8 ft
16	1.86	12,000	Diagonal rolling landing
17	2.06	12,000	Drop 5 ft
18	2.12	12,000	Drop 10 ft
19	2.07	12,000	Drop 10 ft
20	2.11	12,000	Drop 10 ft
21	2.02	12,000	Drop 10 ft
22	2.03	12,000	Drop 15 ft
23	2.11	12.000	Drop 15 ft
24	2.17	12,000	Drop 10 ft
25	2.02	12,000	Drop 15 ft
26	1.82	12,000	Drop 10 ft
27	2.18	12,000	Drop 15 ft
28	1.73	12,000	Drop 10 ft
29	1.91	12,000	Drop 15 ft
30	2.10	12,000	Drop 15 ft
31	1.85	12,000	Rolling landing and taxiing for 10 min

* Estimated gravity force; all other values were recorded on accelerometer.

Photograph 1. Bundles of whole and half panels of AM3 mat



Photograph 2. Whole and half panel of AM3 mat



Photograph 3. Connectors, bolts, and tools required to assemble panels

Photograph 4. Odd-size panels (darker colored) intermixed with other panels in pad complex

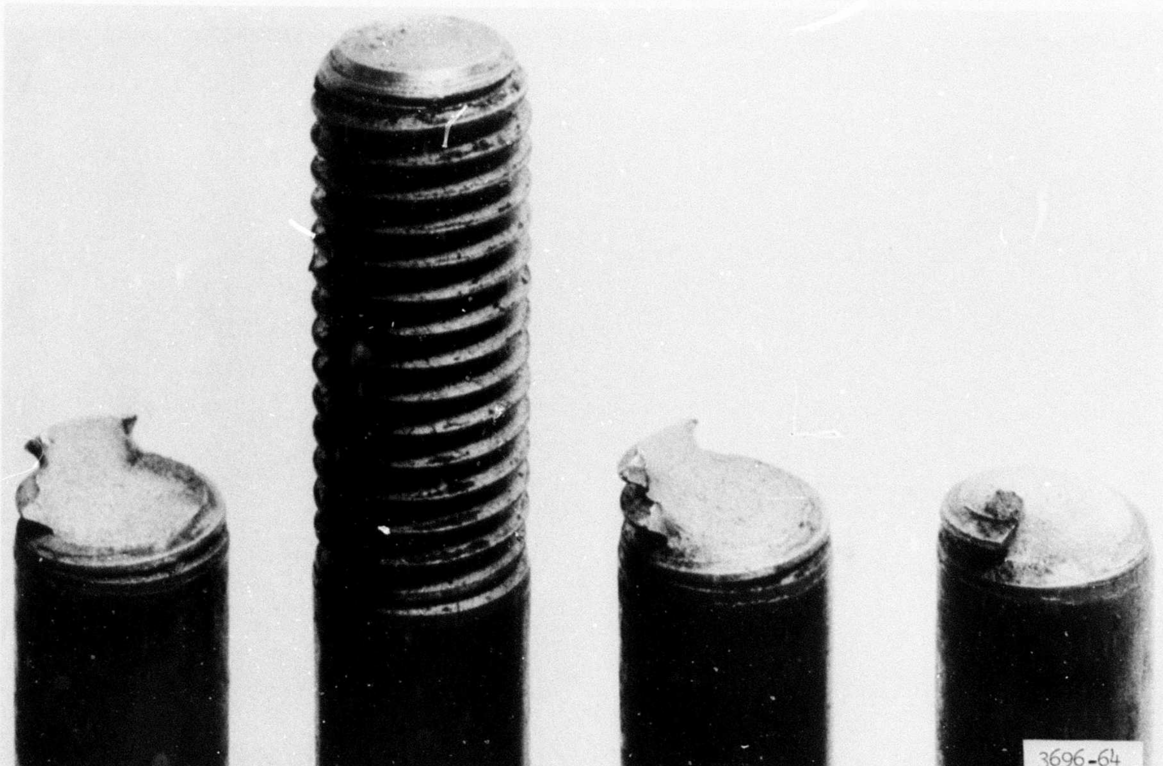
Photograph 5. Site of test Phase I

Photograph 6. Site of test Phase II

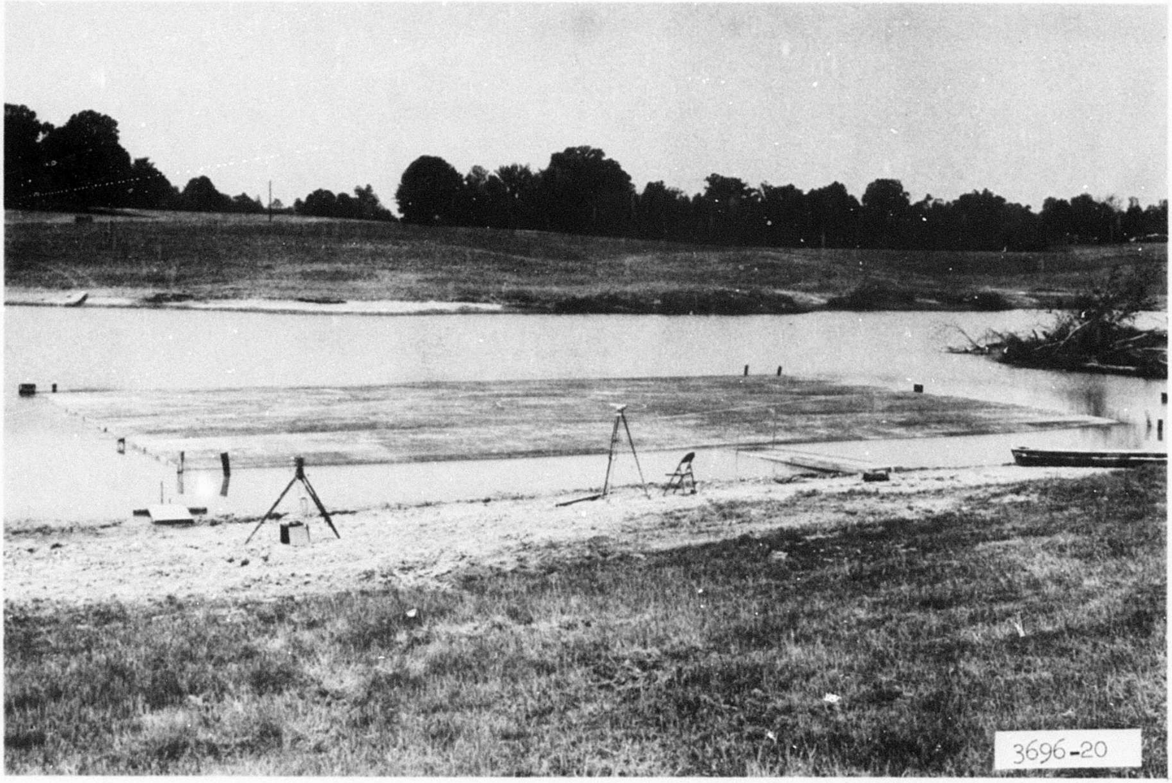
Photograph 7. Assembly of run 4 of pad on pond

Photograph 8. Bow occurred in pad as bolts were tightened after assembly of seven runs

Photograph 9. New panel being forced underwater in order to connect it to pad



Photograph 10. Bolt failures which occurred while recommended torque was being applied



Photograph 11. Completed pad prior to helicopter landings. Note that first and last panel runs are slightly submerged in water

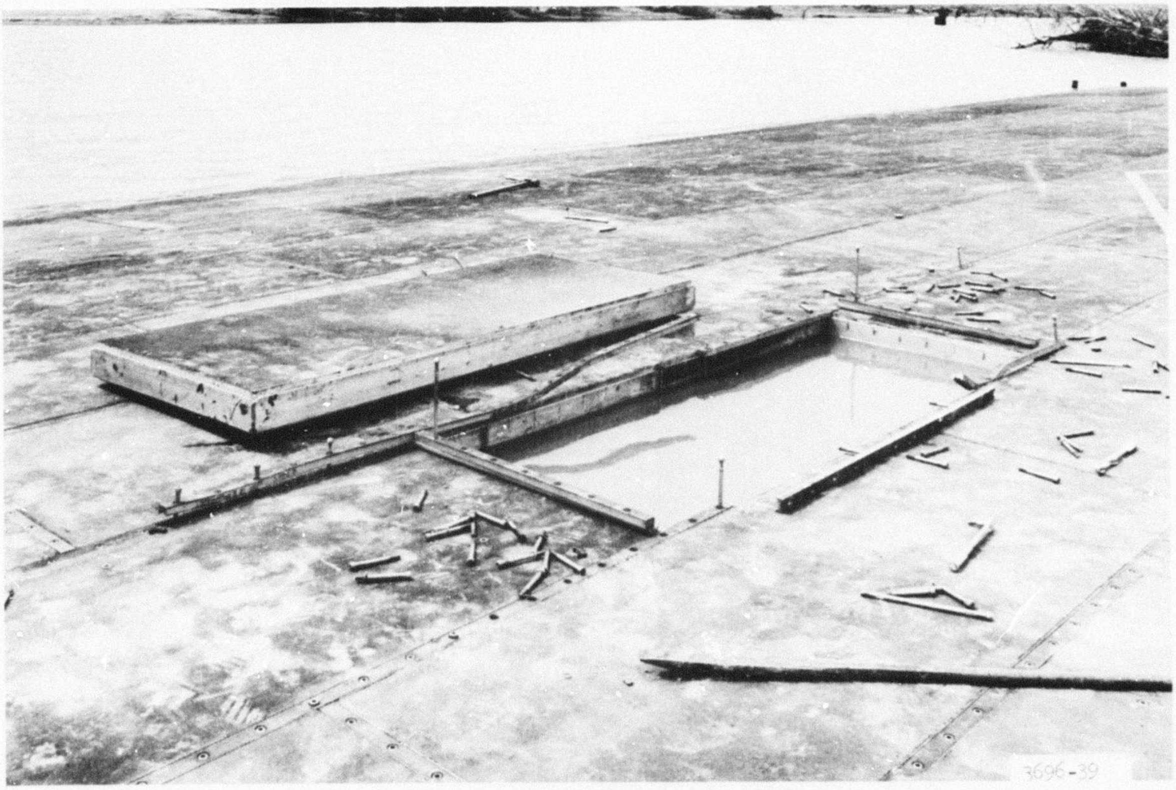
Photograph 12. Closeup of corner of run 1 with edge underwater

Photograph 13. UH-34D helicopter making first landing on pad

Photograph 14. Pad after first helicopter landing

Photograph 15. Taxiing operations with main wheels within 4 ft of edge of pad

Photograph 16. Operations on pad with maximum helicopter load of 13,000 lb

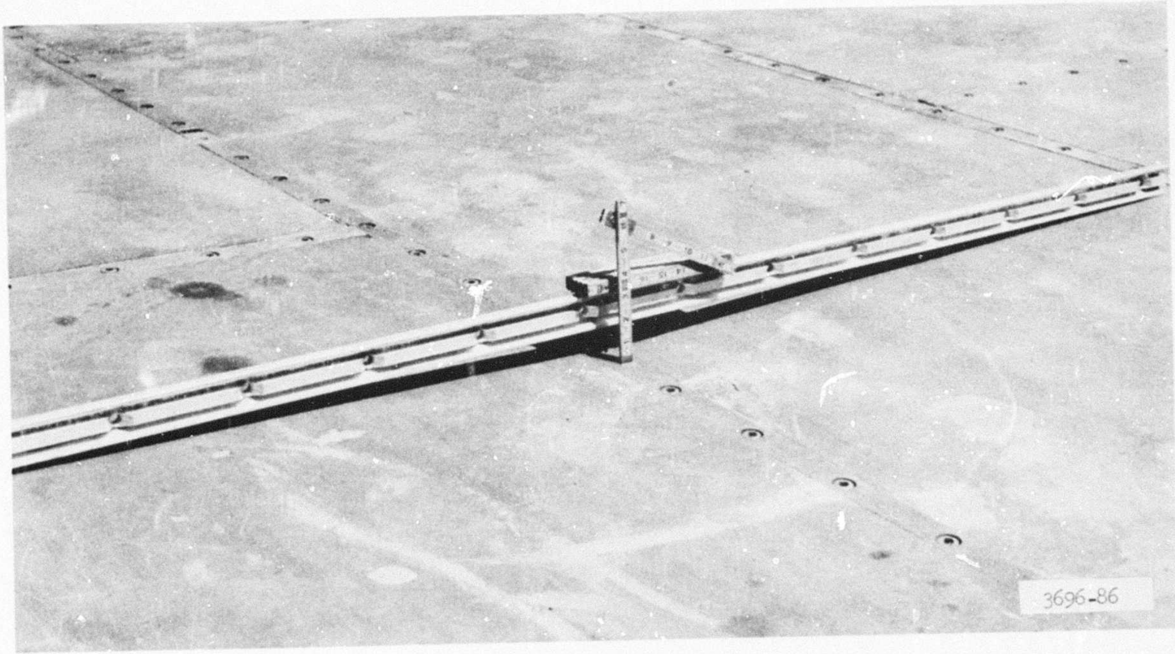


Photograph 17. Panel removed from pad, showing side-connector bars bent and broken during removal

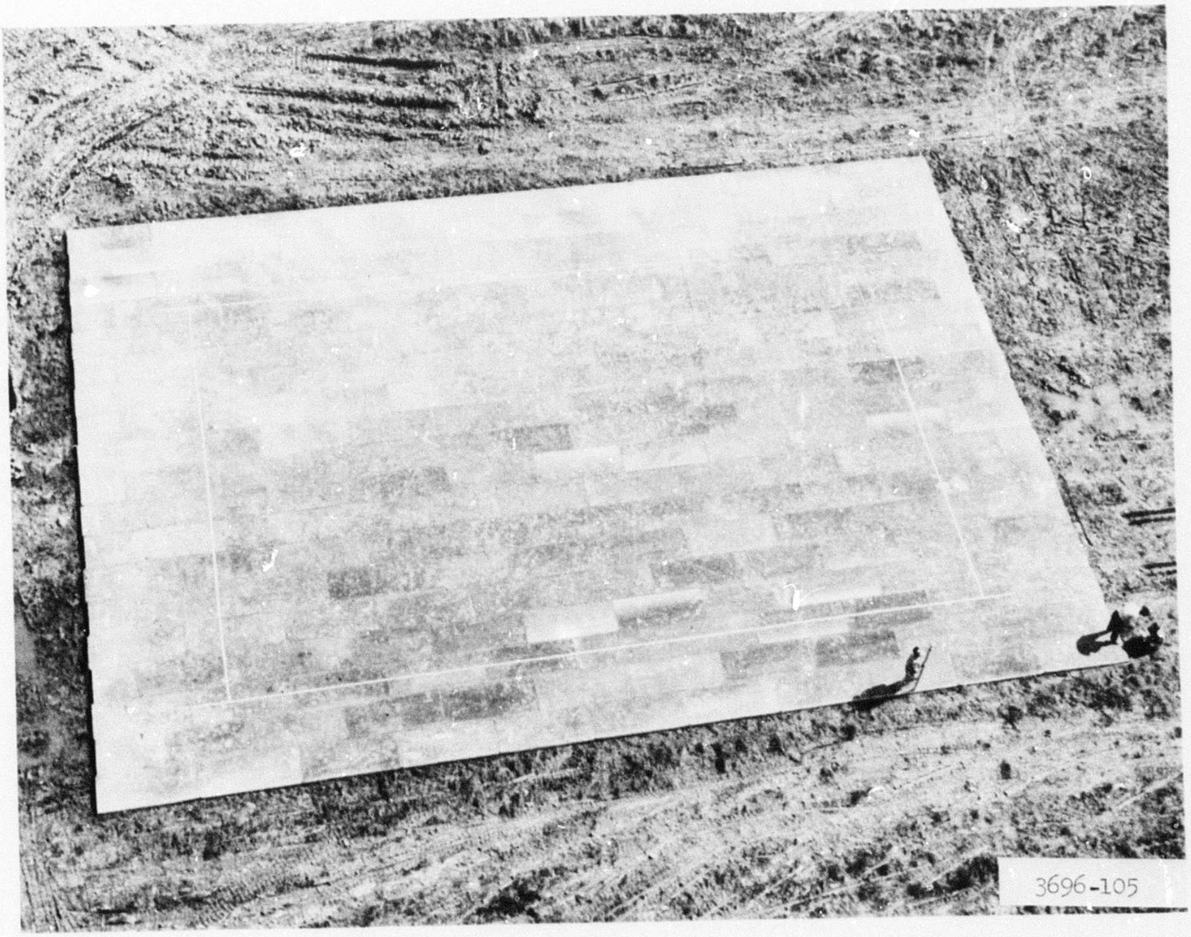
Photograph 18. D4 bulldozer bogged down in marsh near test site

Photograph 19. Test area after placement of two runs of mat. Condition of marsh after foot traffic shown in foreground

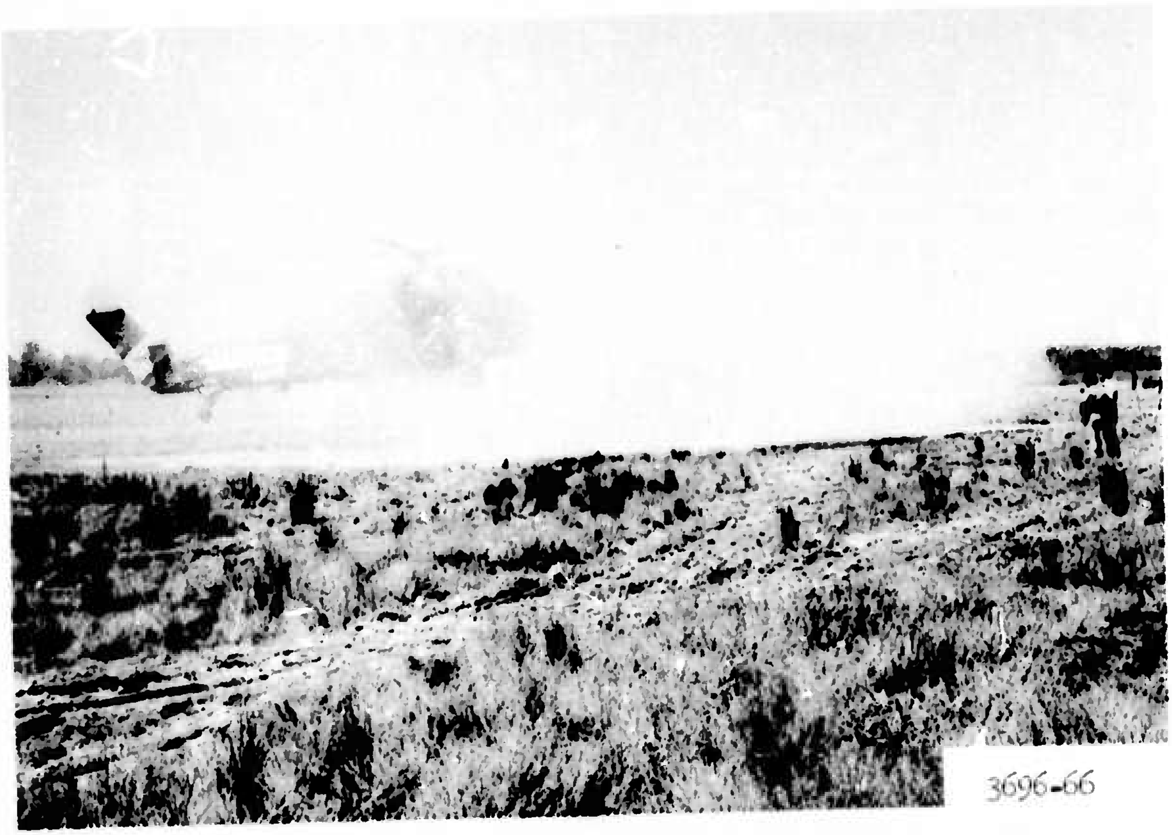
Photograph 20. Tracked vehicle (Weasel) used to tow mat bundles to assembly area. Mat from previous investigations (foreground) used for walkway



Photograph 21. Depression in mat prior to landings, caused by placing panels over depression in ground



Photograph 22. Aerial view of completed pad constructed on marsh



Photograph 23. First landing approach to pad on marsh

Photograph 24. Taxiing operations on pad; gross aircraft weight, 10,000 lb

3696-83

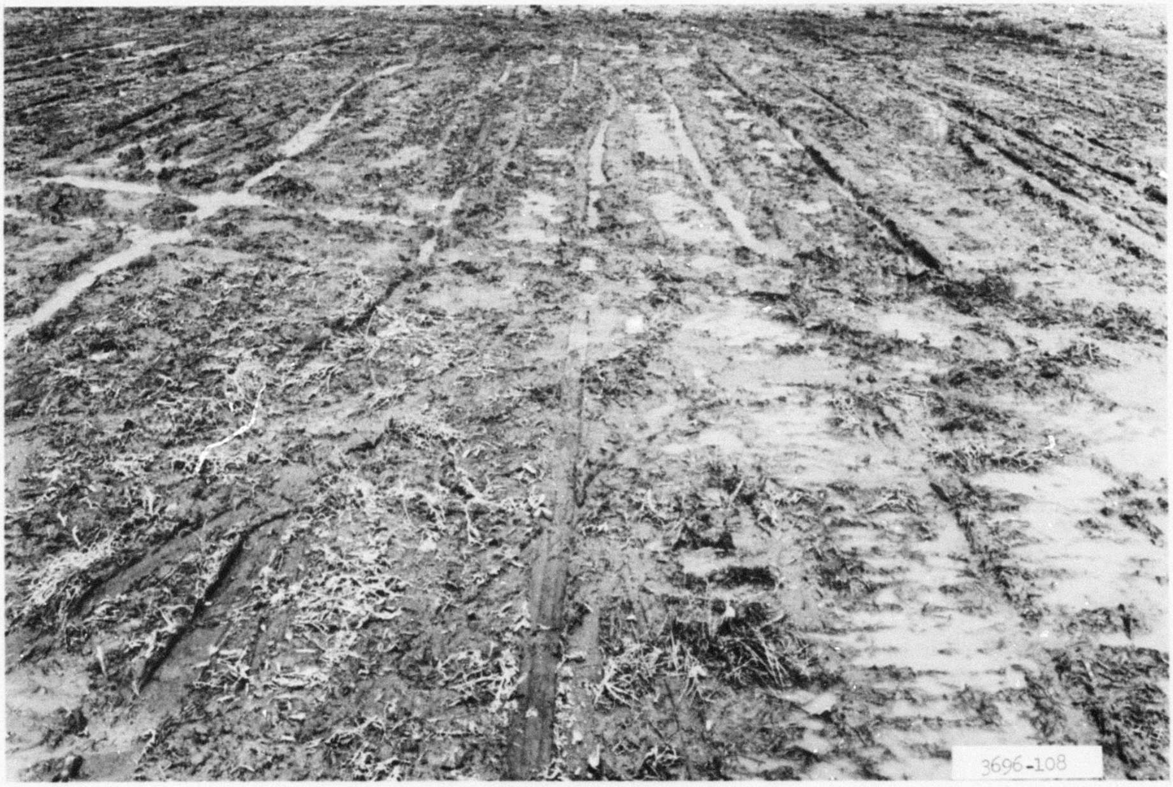
Photograph 25. Helicopter on edge of pad after making a rolling landing across pad; gross aircraft weight, 12,000 lb

3696-86

Photograph 26. Taxiing operations with main load wheels approaching edge of pad (gross aircraft weight, 12,000 lb)

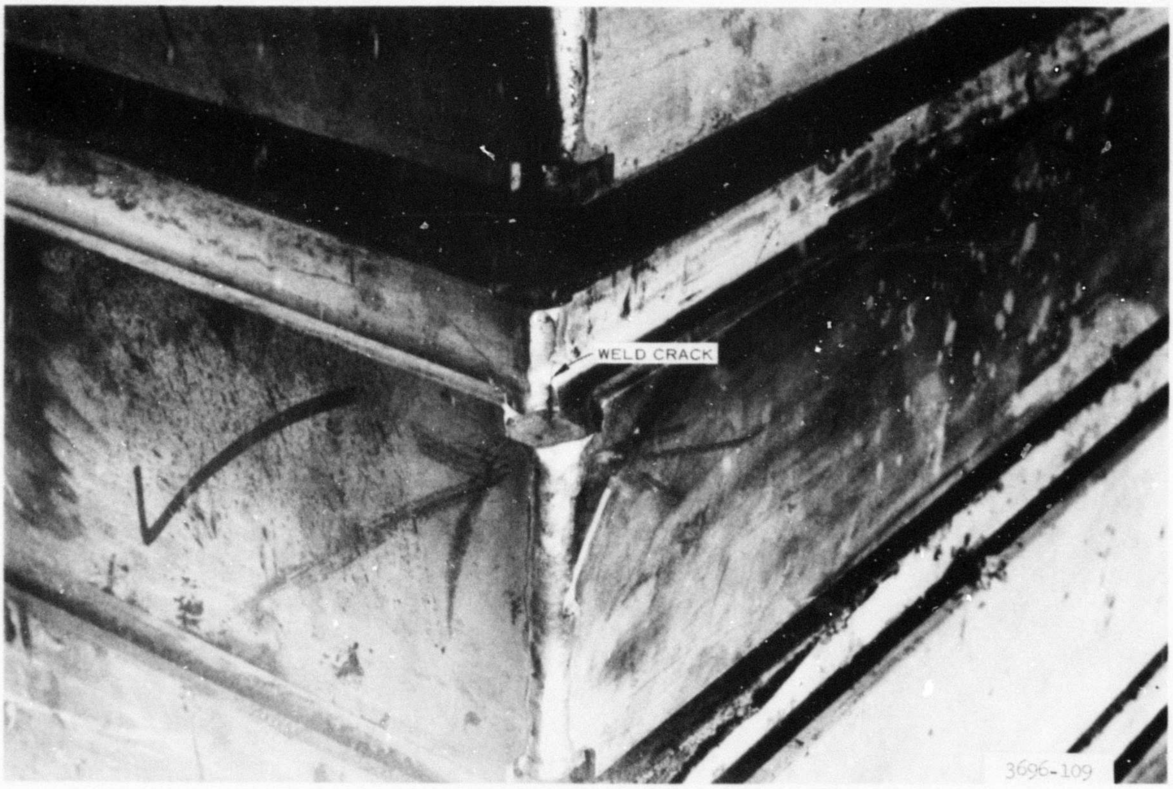
Photograph 27. Tail wheel trafficking depressed area shown in photograph 21

Photograph 28. Main wheel trafficking depressed area shown in photograph 21



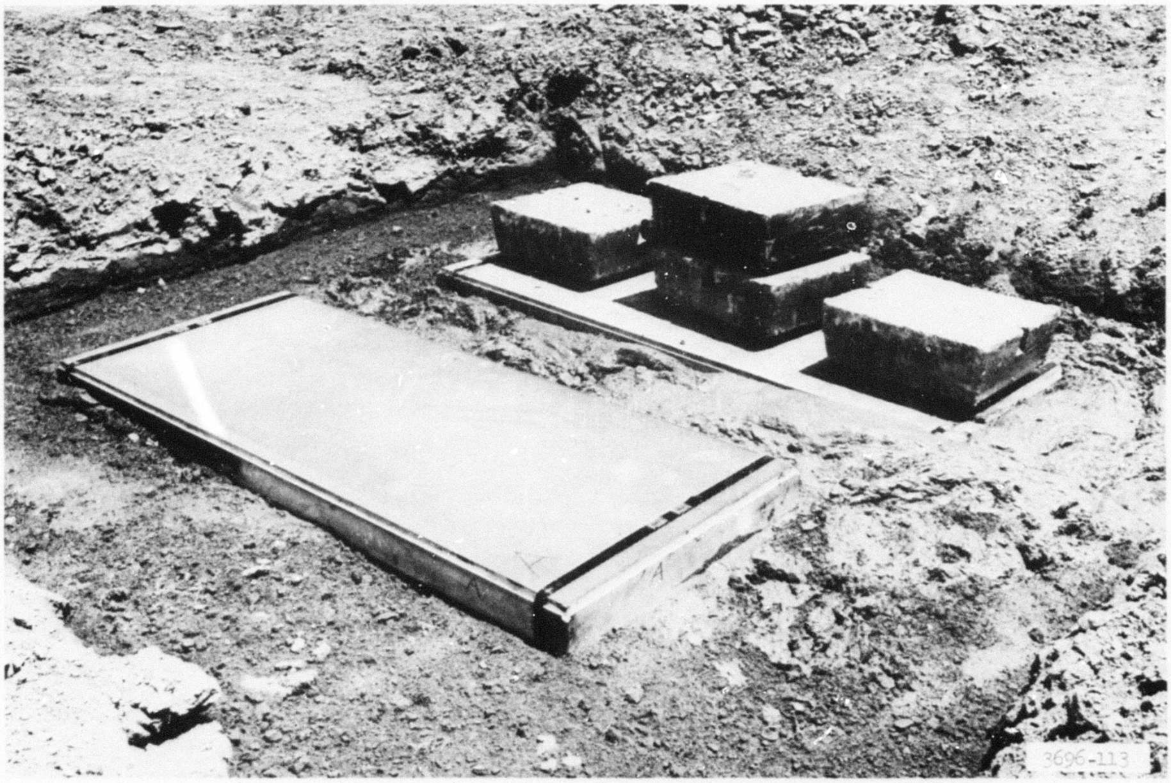
Photograph 29. Marsh immediately after pad removal

Photograph 30. Panel floating with 3-in. freeboard after being submerged for 10 days



Photograph 31. Hairline crack in upper portion of panel corner which allowed water to enter the core

Photograph 32. Pit being flooded in preparation for adhesion tests



Photograph 33. Panels in marsh pit with 8000-lb load on one panel

Photograph 34. Attempt being made to remove panel from muck just prior to steel straps breaking

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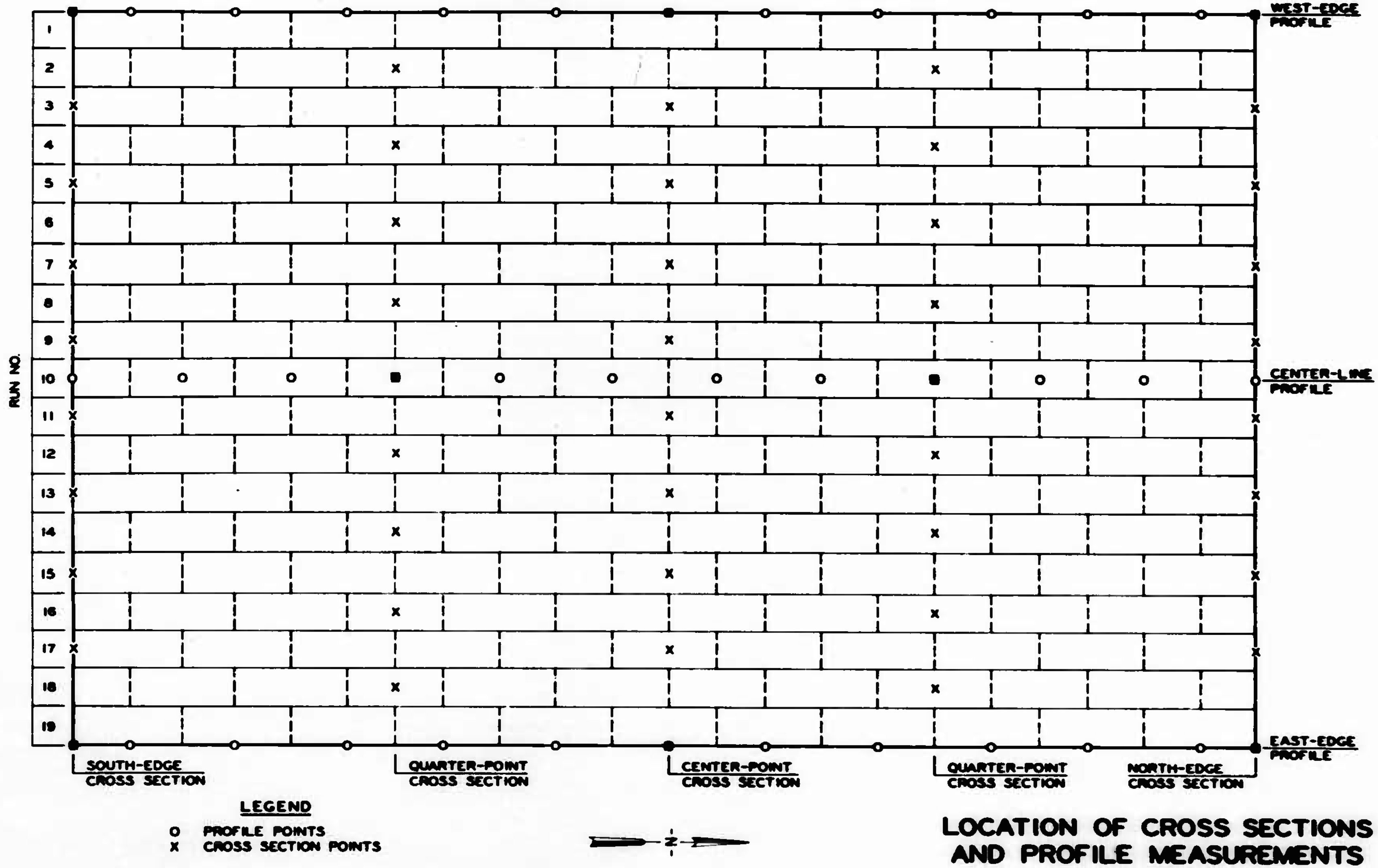
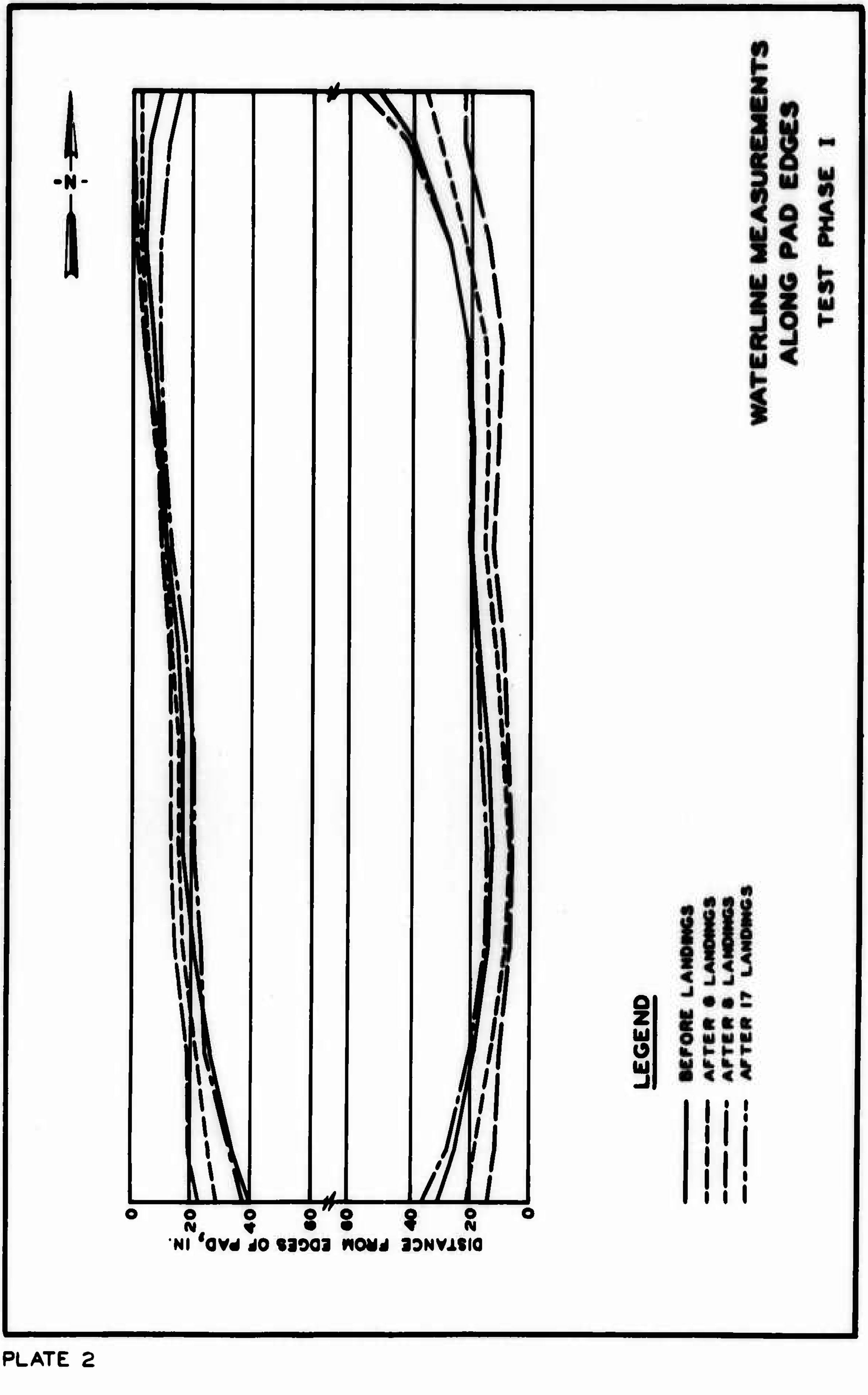


LOCATION OF CROSS SECTIONS AND PROFILE MEASUREMENTS
TEST PHASE I



N
WATERLINE MEASUREMENTS
ALONG PAD EDGES
TEST PHASE I
DISTANCE FROM EDGES OF PAD, IN.
0
20
40
60
80
40
20
0
LEGEND
BEFORE LANDINGS
AFTER 6 LANDINGS
AFTER 8 LANDINGS
AFTER 17 LANDINGS

PLATE 2

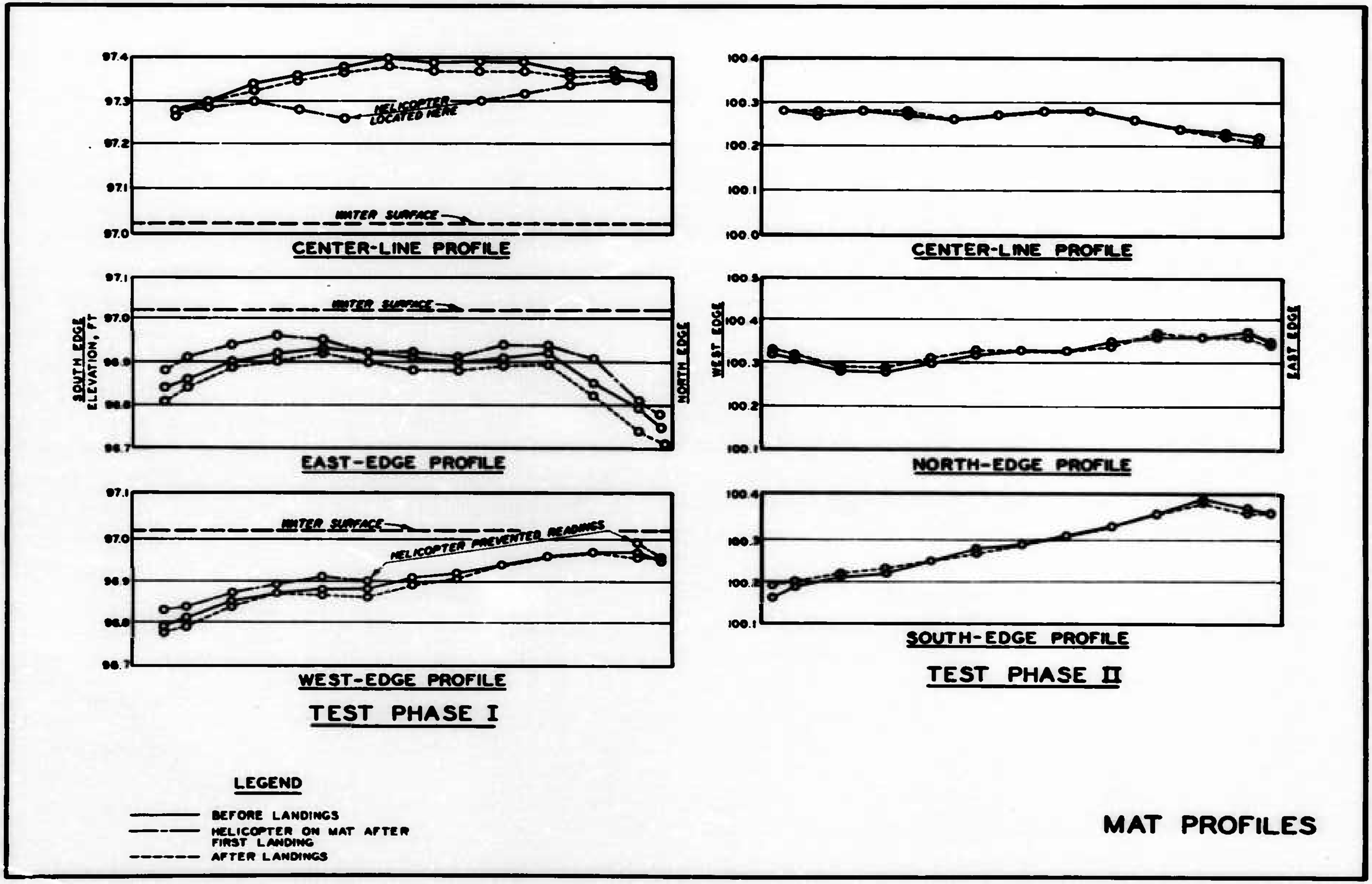
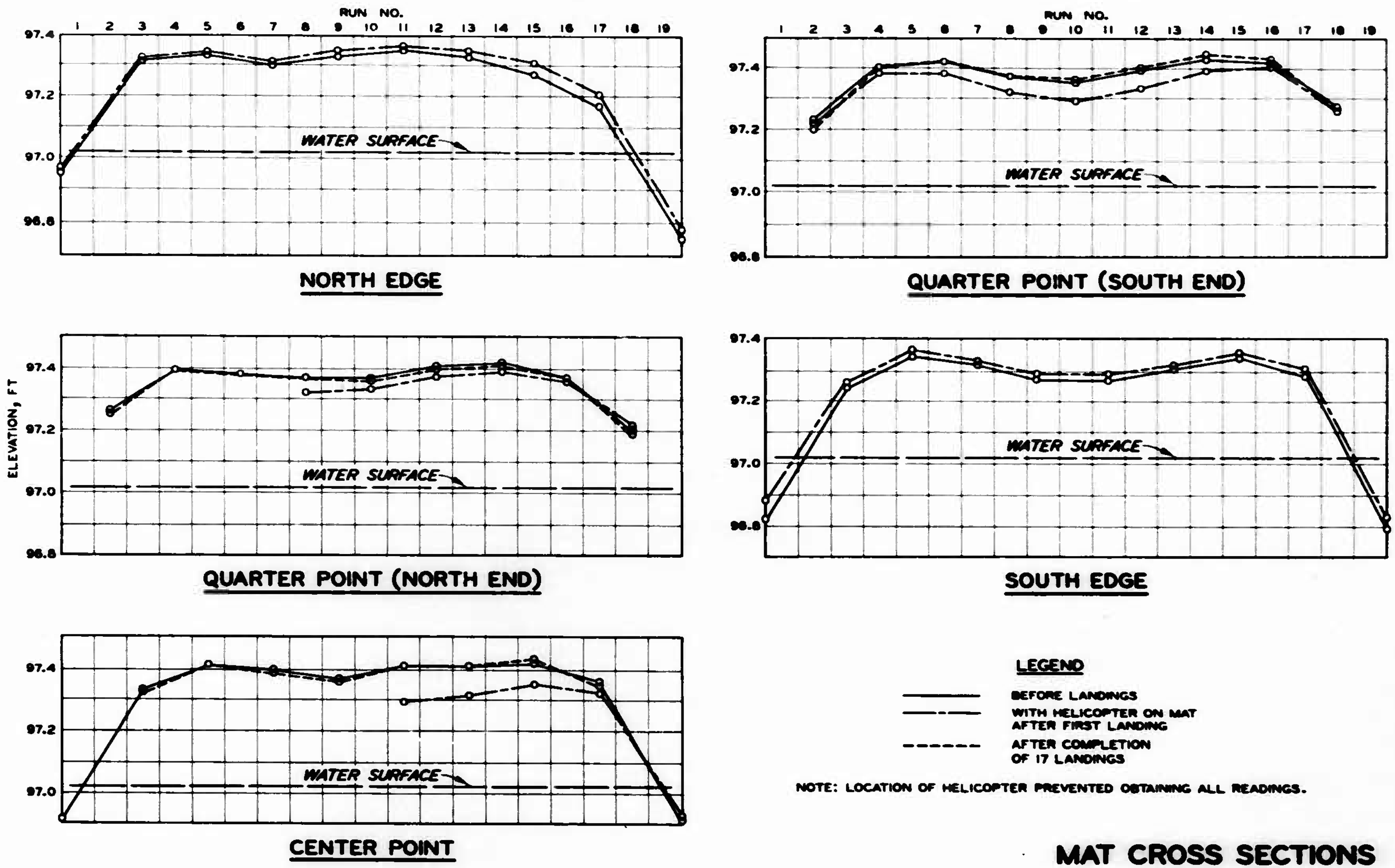

97.4
97.3
97.2
97.1
97.0
HELICOPTER LOCATED HERE
WATER SURFACE
CENTER-LINE PROFILE
97.1
97.0
96.9
96.8
96.7
SOUTH EDGE
ELEVATION, FT
NORTH EDGE
WATER SURFACE
EAST-EDGE PROFILE
97.1
97.0
96.9
96.8
96.7
WATER SURFACE
HELICOPTER PREVENTED READINGS
WEST-EDGE PROFILE
TEST PHASE I
100.4
100.3
100.2
100.1
100.0
CENTER-LINE PROFILE
100.5
100.4
100.3
100.2
100.1
WEST EDGE
EAST EDGE
NORTH-EDGE PROFILE
100.4
100.3
100.2
100.1
SOUTH-EDGE PROFILE
TEST PHASE II
LEGEND
BEFORE LANDINGS
HELICOPTER ON MAT AFTER FIRST LANDING
AFTER LANDINGS
MAT PROFILES

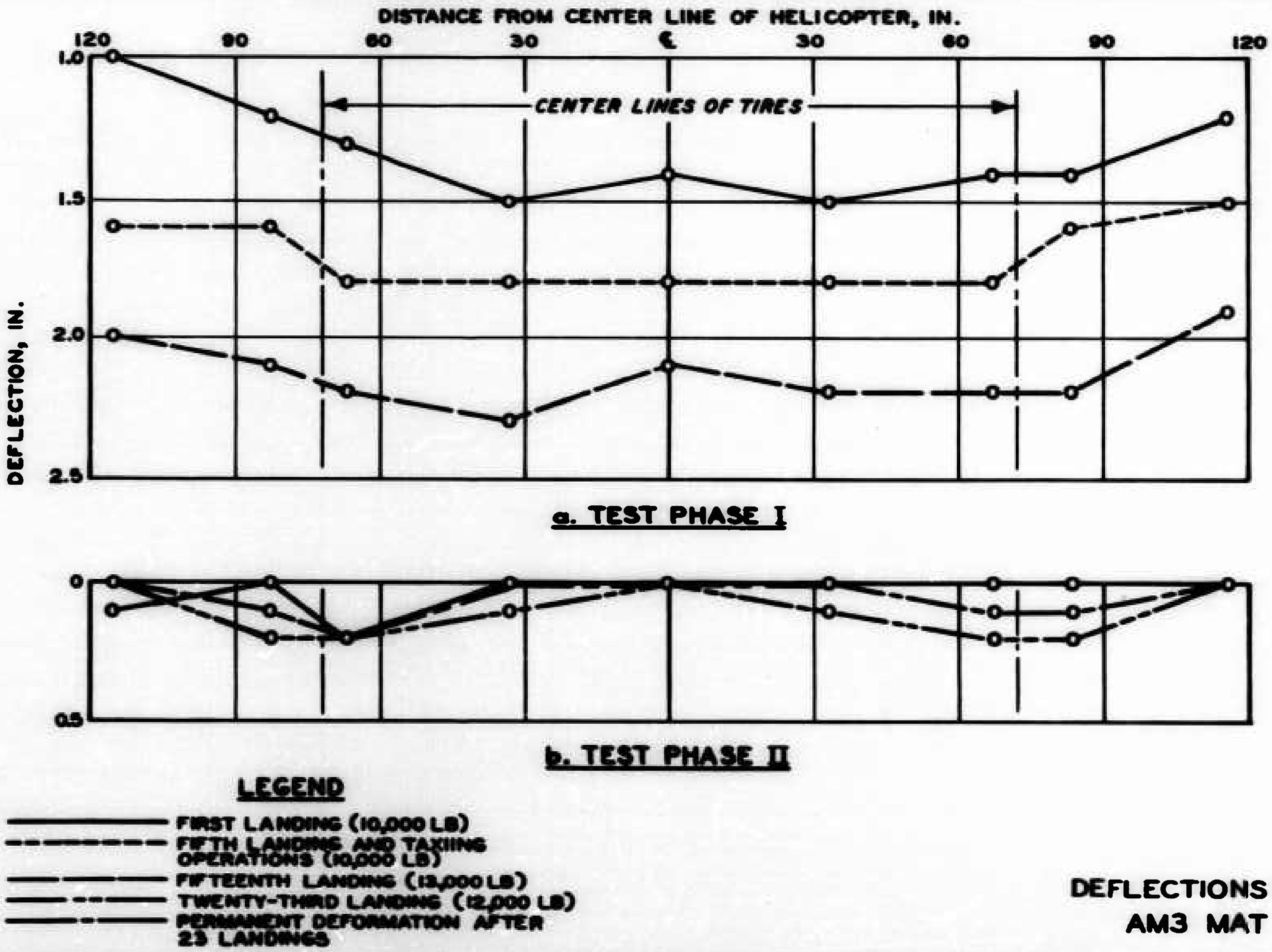
PLATE 3



MAT CROSS SECTIONS

TEST PHASE I

PLATE 4



DEFLECTIONS OF AM3 MAT

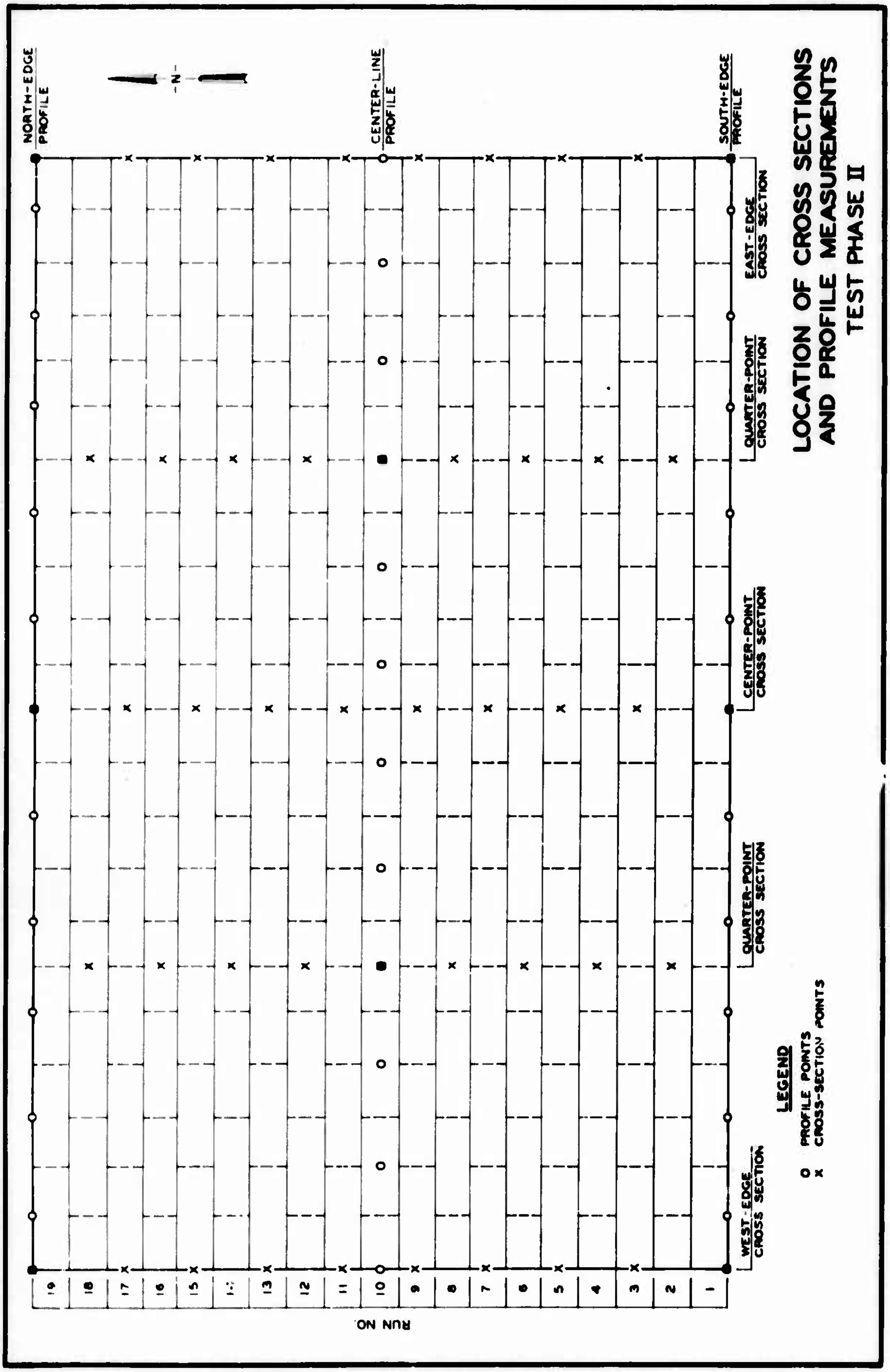
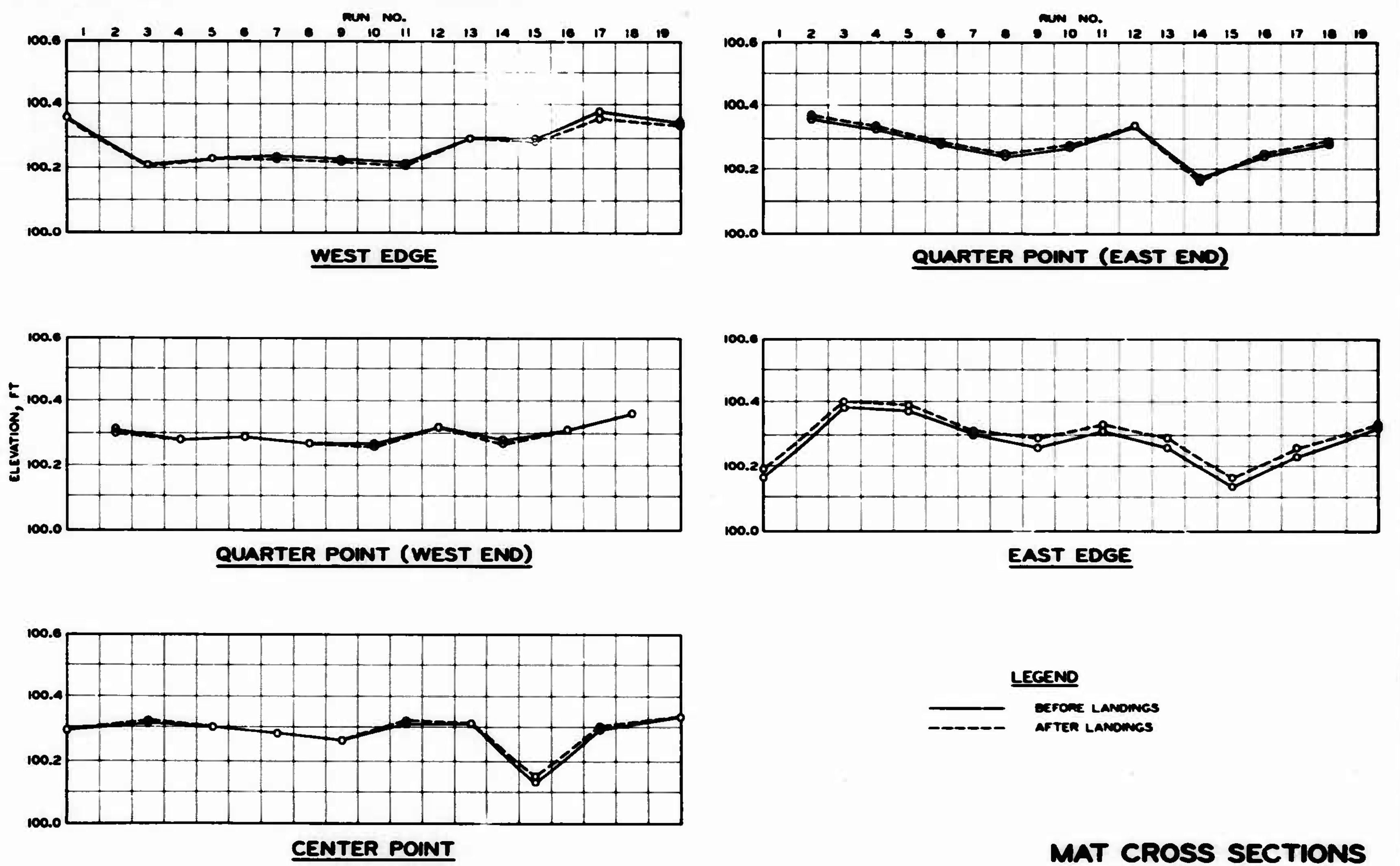
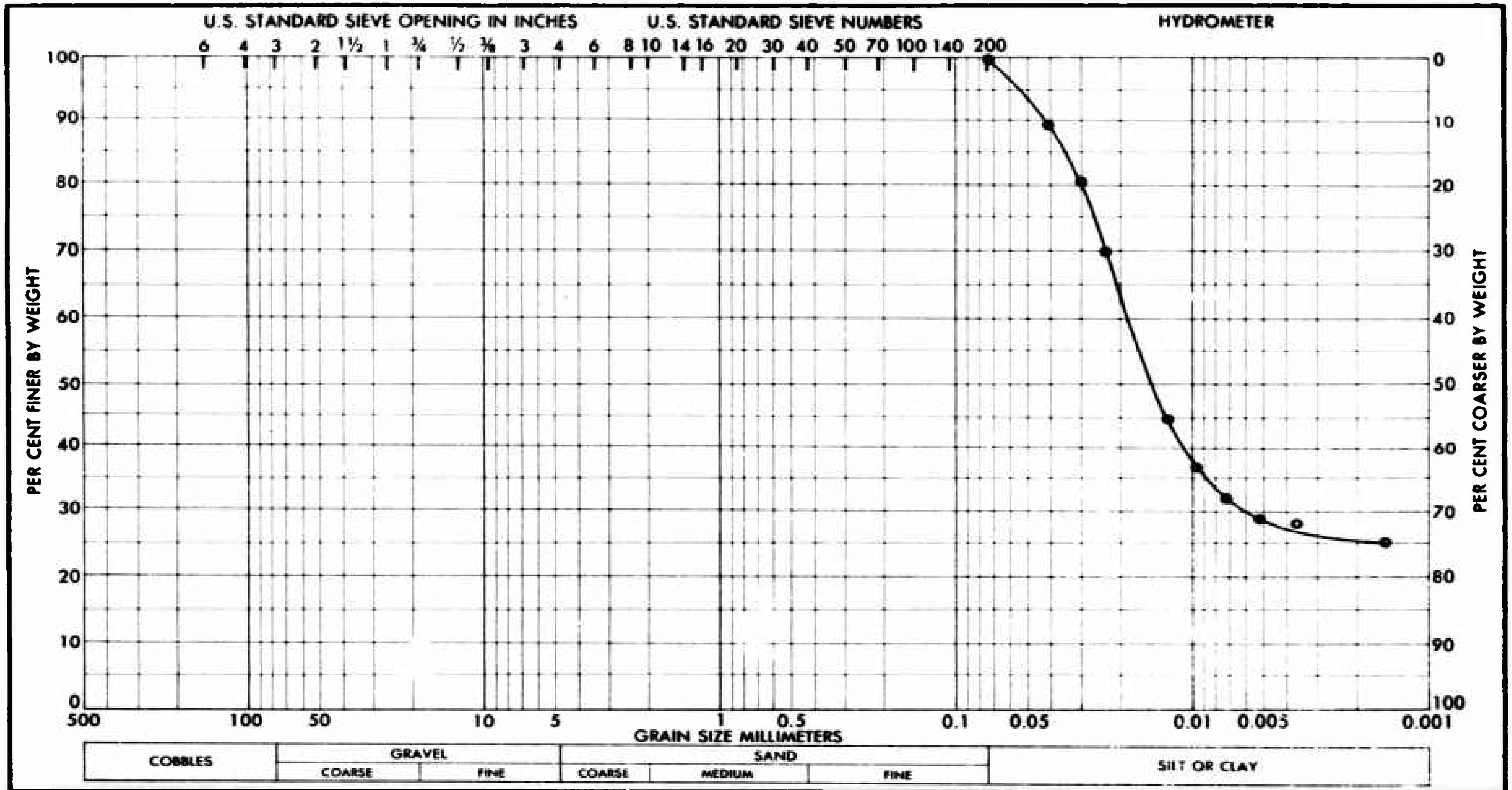

LOCATION OF CROSS SECTIONS AND PROFILE MEASUREMENTS
TEST PHASE II
NORTH-EDGE PROFILE
CENTER-LINE PROFILE
SOUTH-EDGE PROFILE
N
EAST-EDGE CROSS SECTION
QUARTER-POINT CROSS SECTION
CENTER-POINT CROSS SECTION
QUARTER-POINT CROSS SECTION
WEST-EDGE CROSS SECTION
LEGEND
O PROFILE POINTS
X CROSS-SECTION POINTS
RUN NO.
19
18
17
16
15
13
12
11
10
9
8
7
6
5
4
3
2
1

PLATE 6



MAT CROSS SECTIONS
TEST PHASE II



SAMPLE NO.	ELEV OR DEPTH	CLASSIFICATION	NAT W%	LL	PL	PI
AM 3		CLAY (CL)		39	22	17
		SP GR 2.68 (EST)				

GRADATION CURVES

GRADATION AND CLASSIFICATION DATA

MARSH PIT

PLATE 8

APPENDIX A: TEST DIRECTIVE

TEST DIRECTIVE

TD NO. Misc. 86

FROM: DIVISION SUPERINTENDENT (SE- 5) ENGINEERING DEPARTMENT, NAEL (SI)	P. O. 98200/120		DATE: 23 Oct 1964
	J.O.: 49745	EFFORT: N	SHEET 1 OF 3
TO: WES, Vicksburg, Miss. Attn: Mr. McInnis	SUBJECT: Test Procedure for ARPA AM3 Mat at W.E.S., Vicksburg, Mississippi		
	PROJ. ENG.: G. Del Colliano (NE-511)		
	DEV. ENG.: A. Nerenberg (NE-532)		
	AUTHORIZATION: E. O. 64-1084		

REV	DATE	INIT.
	3/2/65	

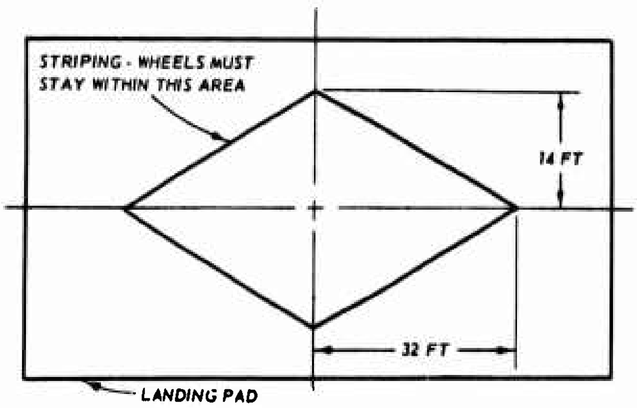
Object: The object of this directive is to delineate the requirements for testing the AM3 landing pad in conjuction with H-21 helicopter.

I. Limits of Test:

A. Test shall be performed on water, as a low limit, and mud as a high limit.

B. Loading limit shall be induced by the H-21 helicopter or equivalent at 15,000 lbs., at an approach speed sufficient to give a 2.00 g maximum vertical deceleration of the aircraft.

C. The 62 ft. x 90 ft. landing pad is designed to withstand a maximum C.G. eccentricity of 7 ft. off dead center. It is therefore imperative that a "safe area" be striped off on the pad, using a reflective, removable tape. (See sketch below.)



NO. OF INFORMATION COPIES TO			
SE-34		SM-2	
SE-39		SM-3	
SE-532	2	ST	
SE-		WES	6
SE-511 (RE)	1	NE-531	1

ENCLOSURE (/) TO NAEC LTR

1243 SERIAL

12 MAR 1965 DATE

PREPARED: M. K. Blevins

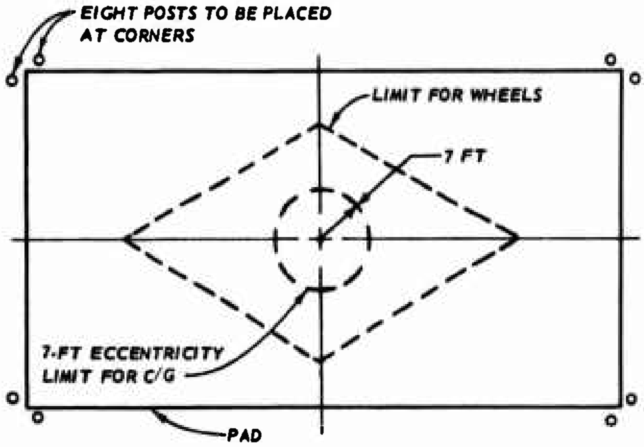
APPROVED: E. J. Seidenglanz BY DIRECTION

II. Measurements:

A. With the pad on mud, elevations shall be taken at frequent intervals before, during, and after each test.

B. In order to determine the loading of the mat, the helicopter shall be equipped with an accelerometer near its C.G., with a range of at least 2.00 g's for H-21. Records from this instrument shall be preserved.

C. With the pad on water, freeboard measurements shall be taken, with the pad unloaded, loaded dead center with the H-21, and loaded at various degrees of C.G. eccentricity up to the limit of 7 ft. (See sketch below.) Elevations shall be taken as above, when possible.



D. Take diagonal dimensions of the pad.

E. After completing parts 1 and 2 under Phase III, take diagonal dimensions again. This will check for planar distortion.

III. Testing:

A. On both mud and water, land the helicopter on the pad at increasing loads, starting with the minimum attainable approach, and increasing by the smallest practical increment of (g) loading, up to a maximum of 2.00 g's for H-21.

B. The test on water shall be the first test conducted. Since measurement control may be difficult, color motion pictures shall be taken during the approaches, with a suitable reference for measurement, such as a unit grid system relative to the earth.

C. The mud test shall follow. Elevations shall be recorded after every loading. Data should be recorded concerning any phenomenon which might occur out of the ordinary. Motion picture coverage is required.

1. Subordinate Tests:

a. The pad shall be subjected to a brief taxiing test (10 passes within eccentricity limits) by the helicopter, noting deflections of joints, and any changes in elevation points.

IV. Miscellaneous Requirements:

A. Ambient conditions shall be regularly noted.

B. Landing pad to be installed flat, with the standard matting surface roughness. (No greater than 1/8" deflection at any point along a 12" straightedge)

V. Reporting:

A. It is requested that NAEL(SI) receive a copy of the WES formal test procedure prior to the start of the test. This shall include sample data sheets. This information will familiarize NAEL(SI) with the method of testing and taking data, and will enable NAEL(SI) to analyze (more aptly) subsequent information.

B. A daily report shall be submitted which shall include all information gained that day. The report shall terminate with a brief analysis of test data to date. These shall be sent by registered mail to Commanding Officer, Naval Air Engineering Laboratory (SI), Naval Air Engineering Center, Philadelphia, Pa. 19112, Attn: NE-532.

C. Any important information which needs immediate attention by NAEL(SI) shall be conveyed by telephone but repeated by inclusion in that day's report.

D. Photographs taken shall be processed, documented, and forwarded to NAEL(SI) within a week.

E. A final report shall be forwarded to NAEL(SI) within six (6) weeks of completion of tests. This report shall be a condensation of all daily reports and pictures, along with a set of reduced data, presented in a form which reflects any or all trends of pad performance.